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FIELD STUDIES OF CERTAIN DISEASES OF SNAP BEANS IN THE SOUTHEAST[1]

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EFFECTS OF SOME CULTURAL METHODS ON DEVELOPMENT OF DRY ROOT ROT ON SNAP BEANS

Root rots on snap beans are common throughout the southeastern part of the United States, appearing at least to a limited extent in all seasons and becoming of serious importance in some. Since plantings along the Atlantic seaboard are made over a long period of time and under varied soil and climatic conditions, considerable differences in losses from diseases appear from one area to another and from year to year. During the course of a general study of bean root rots in the South there was opportunity to study the development of dry root rot (*Fusarium martii phaseoli* Burk.) under varied cultural practices.

Burkholder (*2*)[3] describes in detail dry root rot as it appears in New York. This description is also typical of the disease as it occurs in the South. He reports that soil and fertilizer treatments were not effective as control measures under central New York conditions. Later, he reports (*3*) dry root rot as being particularly severe in soils

[1] Received for publication March 22, 1938. These investigations were conducted at the Truck Experiment Station, Charleston, S. C., from 1931 to 1936, under cooperative arrangement with the South Carolina Agricultural Experiment Station. It is believed that the results are applicable to the Middle and South Atlantic seaboard area.

[2] Acknowledgment is made to L. L. Harter, of the Division of Fruit and Vegetable Crops and Diseases, for valuable suggestions during the course of the work and for helpful criticisms of the manuscript; also to B. L. Wade and Victor R. Boswell, of the same Division, for assistance in the analysis of the data and in the preparation of the manuscript.

[3] Italic numbers in parentheses refer to Literature Cited, p. 27.

of low moisture content. Although literature on the effect of cultural practices in relation to root rot is limited, the influence of moisture conditions is clearly shown.

MATERIALS AND METHODS

The Stringless Black Valentine variety of bean was used throughout this study except in 1932, when the Bountiful variety was used. Rows 100 feet long, replicated systematically three or more times, were used in all cases except in the fertilizer tests, when quadruplicate 1/60-acre plots were laid out. Each series of plots was located on a different area of land each year. Tests were designed to study the effect of depth of planting, of the time of planting, of various types of fertilizers, and of fertilizer placement on the development of dry root rot. Root rot readings were made just before the first blooming date in all cases.

The data were analyzed by Snedecor's (*21*) modification of Fisher's method of analysis of variance and by Wallace and Snedecor's (*22*) methods of machine calculation.

RESULTS

DEPTH OF PLANTING

The percentages of dry root rot in uniform samples of plants, the stands, and the yields, from plots planted at depths of 0.5, 1, and 2 inches, respectively, are shown in table 1. It will be noted that considerable differences in percentage of root rot infection appear between the different depths, likewise between years. The fact that the 2-inch depth consistently showed more root rot than the other depths raises the question of the influence of greater moisture that was present at that depth. Since this result appears to be in contradiction to the findings of Burkholder, another explanation is indicated. Damage to the root system at the 2-inch depth from damping-off fungi may have made infection by the dry root fungus easier. Even so, the root rot appeared to cause no appreciable damage, as evidenced by lack of correlation between root rot and yield.

Table 2 presents the results of statistical analysis of the data for table 1.

Moderately significant differences in dry root rot infection occurred between years, but the response to planting depth was quite consistent year after year, as shown by the low variance for interaction of planting depth $\times$ years and its significant difference as compared with variance due to planting depth. (Observed $F=6.87$; 5-percent point$=5.14$.) Highly significant differences in stand and in yield occurred between years, as might be expected in a field study, and variances due to interaction between planting depths and years are also highly significant. Variances in stand and in yield due to planting depth are not significantly greater than those due to depth $\times$ year, further confirming the variable behavior of treatments in different years.

Analysis of covariance (table 2) showed no significant correlation of either stand or yield with dry root rot in any case. It is recognized, however, that highly significant values are hardly to be expected for such data showing only 1 to 5 degrees of freedom. The coefficient of correlation between stand and yield for total variance was surprisingly near zero, but for remainder or error a low, significant value of

+0.481 was obtained. Competition evidently played a large part in tending to equalize yields among plots of variable stand but which were otherwise under similar conditions.

TABLE 1.—*Relation of planting depth to stand, to percentage of dry root rot infection, and to yield of snap beans*

[Triplicate plots]

PLANTS PER PLOT

Year	Variety	Results at planting depth of—			
		½ inch	1 inch	2 inches	Mean [1]
		Number	*Number*	*Number*	*Number*
1932	Bountiful	371	345	269	327
1934	Stringless Black Valentine	141	322	281	248
1935	do	481	499	526	502
1936	do	532	652	616	600
Mean [2]		381	454	423	419

PLANTS INFECTED WITH DRY ROOT ROT

		Percent	*Percent*	*Percent*	*Percent*
1932	Bountiful	4.7	26.0	39.3	23.3
1934	Stringless Black Valentine	2.7	13.3	28.0	14.7
1935	do	2.7	6.7	14.0	7.8
1936	do	11.3	8.7	15.3	11.8
Mean [2]		5.3	13.7	24.2	14.4

YIELD PER PLOT

		Pounds	*Pounds*	*Pounds*	*Pounds*
1932	Bountiful	9.5	10.1	9.7	9.8
1934	Stringless Black Valentine	17.3	34.8	33.5	28.5
1935	do	30.6	30.7	36.2	32.5
1936	do	14.8	14.3	13.4	14.1
Mean [2]		18.0	22.5	23.2	21.2

[1] Differences required for significance between years are: 41 plants for stand, 10 percent for dry root rot, and 2.7 pounds for yield.

[2] Differences required for significance between planting depths are: 36 plants for stand, 8.7 percent for dry root rot, and 2.3 pounds for yield.

TABLE 2.—*Analysis of variance and covariance of data entering into table 1*

Source of variation	Degrees of freedom	Mean squares for—			Degrees of freedom	Coefficients of correlation between—			Minimum significant value of *r*
		Stand	Dry root rot	Yield		Dry root rot and stand	Dry root rot and yield [1]	Stand and yield [2]	
Total	35	23,871.3	217.3	118.2	34	−0.190	−0.099	+0.039	0.325
Between planting depths	2	[3] 16,070.5	[3] 1,068.8	[1] 95.06	1	+.505	+.896	+.835	.997
Between years	3	[3] 232,000.2	[4] 391.8	[3] 1,085.9	2	−.593	−.720	−.103	.950
Between replicates	2	118.6	[4] 439.2	27.2	1	+.833	+.623	+.954	.997
Depths × years	6	[3] 10,914.6	155.6	[3] 75.0	5	−.514	+.187	+.678	.754
Remainder (error)	22	1,892.2	112.8	8.3	21	+.128	+.038	+.481	.413

[1] Coefficients of partial correlation between dry root rot and yield with stand held constant are: For total variance, −0.093; for error, −0.027.

[2] Coefficients of partial correlation between yield and stand with dry root rot held constant are: For total variance, +0.066; for error, +0.481.

[3] Significant with reference to error; odds greater than 99:1.

[4] Significant with reference to error; odds greater than 19:1 but less than 99:1.

The values for partial correlation further confirm the fact that the amount of dry root rot encountered in these particular studies was without effect on yield. The tendency toward positive correlations between dry root rot and yield for variance due to planting depth and to replicates might appear anomalous, but it should be recalled that the root rot data represent only percentage infection instead of estimated severity. Although the coefficients in question are insignificant, they do suggest that the best planting conditions from the standpoint of plant growth also happen to be most conducive to root rot infection. It does not necessarily follow that they are likewise most conducive to root rot damage. On the contrary, it would seem that those very conditions of planting conducive to root rot infection in this study were so favorable to plant development that the parasite was more or less outgrown.

TIME OF PLANTING

Numerous check plots in connection with certain seed treatments (p. 17) were planted in each of 6 years at three different periods—the first immediately after the spring frost-free date and the other two at successive, approximately 2-week intervals. The ranges of planting dates were: March 1 to 10, March 15 to 25, and March 25 to April 5. Percentages of root rot infection were determined for each of the 6 years, but in 1936 complete stands were not counted, and in 1935 only two of the three plantings were worth harvesting.[4] Consequently, complete data as shown in tables 3 and 4 are available for but 4 years.

The quadruplicate plots of each planting in each year were located within a single block, each planting in the seed-treatment study from which these data were obtained being planted as a solid block. Such an arrangement, of course, may detract from the maximum usefulness of replicates and of treatments, but since several years are involved and the experiment was planted on a different area each year, and since the replicate checks in question were well separated by distance, it is believed that there is reasonable foundation for treating the data as presented here.

Table 3 shows an apparent tendency for root rot infection to decrease as planting data is delayed, but the differences between means of planting dates are not significant. Marked differences in root rot occurred between years. There were significant differences in stand and in yield between planting dates and between years.

As in the study of effect of depth of planting discussed above, the degree of root rot observed appeared to be quite without effect on yield, especially if the coefficients of correlation and partial correlation for error covariance be considered. The partial correlation between the percentage of root rot and yield with stand held constant showed a significant coefficient of $+0.315$ for total covariance, but this apparent anomaly was doubtless due to the low intensity of the root rot in all instances, together with the longer, more favorable growing and bearing period available for the earlier plantings. Despite the tendency toward less root rot on the later plantings and their better stands, other conditions that were quite adverse tended to cut the latest crops short.

[4] Plantings made about April 1 or later sometimes encounter such adverse weather and disease conditions that the crop is a failure.

TABLE 3.—*Relation of time of planting to stand, to percentage of dry root rot infection, and to yield of snap beans*

[Quadruplicate plots]

PLANTS PER PLOT

Year	Variety	Results from planting— Mar. 1–10	Mar. 15–25	Mar. 25–Apr. 5	Mean [1]
		Number	*Number*	*Number*	*Number*
1931	Stringless Black Valentine	314	348	340	334
1932	Bountiful	173	307	353	278
1933	Stringless Black Valentine	249	285	340	291
1934	do	359	459	446	421
Mean [2]		274	350	370	331

PLANTS INFECTED WITH DRY ROOT ROT

		Percent	*Percent*	*Percent*	*Percent*
1931	Stringless Black Valentine	31.3	22.8	15.5	23.2
1932	Bountiful	15.8	10.5	15.5	13.9
1933	Stringless Black Valentine	7.8	12.8	3.5	8.0
1934	do	7.0	4.0	1.5	4.2
Mean		15.5	12.5	9.0	12.3

YIELD PER PLOT

		Pounds	*Pounds*	*Pounds*	*Pounds*
1931	Stringless Black Valentine	24.4	29.3	23.3	25.7
1932	Bountiful	5.0	11.1	32.7	16.3
1933	Stringless Black Valentine	23.3	28.5	2.5	18.1
1934	do	25.6	27.3	12.8	21.9
Mean [3]		19.6	24.0	17.8	20.5

[1] Differences between years required for significance are, respectively, 36 plants, 6.2 percent and 5.0 pounds.
[2] Difference required for significance is 31 plants.
[3] Difference required for significance is 4.3 pounds.

TABLE 4.—*Analysis of variance and covariance of data entering into table 3*

Source of variation	Degrees of freedom	Mean squares for— Stand	Dry root rot	Yield	Degrees of freedom	Coefficients of correlation between— Dry root rot and stand	Dry root rot and yield [1]	Stand and yield [2]	Minimum significant value of *r*
Total	47	7,051.01	122.69	120.66	46	−0.224	+0.227	+0.299	0.273
Between planting dates	2	[3] 41,140.15	161.69	[4] 164.21	1	−.943	+.329	+.046	.997
Between years	3	[3] 50,434.61	[3] 821.35	[3] 208.18	2	−.384	+.464	+.571	.950
Between replicates	3	1,247.22	[4] 201.69	4.38	2	+.056	−.505	−.414	.950
Dates × years	6	[4] 5,091.76	79.35	[3] 578.31	5	+.357	+.483	+.377	.754
Remainder (error)	33	1.927.89	57.51	37.43	32	+.030	+.018	+.381	.325

[1] Coefficients of partial correlation between dry root rot and yield with stand held constant are: For total variation, +0.315; for error, +0.007.
[2] Coefficients of partial correlation between stand and yield with dry root rot held constant are: For total variation, +0.368; for error, +0.381.
[3] Significant with reference to error; odds greater than 99 : 1.
[4] Significant with reference to error; odds greater than 19 : 1 but less than 99 : 1.

It thus appears that under the conditions of these studies, controlling time of planting—within the range of common practice—is of no great importance as a means of controlling root rot damage. Time

of planting is of great importance for other reasons in relation to yields of snap beans.

COMPOSITION OF FERTILIZER

The dry root rot data on beans grown in plots receiving different percentages of nitrogen, phosphorus, and potash, also in plots receiving different amounts of a 5–7–5 fertilizer, are shown in table 5. It is apparent from these data that neither varying the proportions of nitrogen, phosphorus, and potash nor varying the amounts of a common complete fertilizer materially affected the development of dry root rot.

TABLE 5.—*Percentage of Stringless Black Valentine bean plants infected with dry root rot on plots treated with various types and varying amounts of fertilizer*

Year	Dry root rot infection following fertilizer applications per acre of—							
	1,000 pounds 0–7–5 [1]	1,000 pounds 3–7–5	1,000 pounds 5–7–5	1,000 pounds 7–7–5	1,000 pounds 5–0–5	1,000 pounds 5–5–5	1,000 pounds 5–7–5	1,000 pounds 5–10–5
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1933	3.75	6.25	4.50	6.25	3.00	6.25	4.50	3.25
1934	1.50	1.00	1.00	2.00	2.25	1.25	2.00	0
1935	8.25	6.00	11.25	7.00	8.75	5.50	7.50	6.25
1936	7.25	5.50	6.00	6.25	4.75	7.00	6.00	5.25
Mean	5.18	4.68	5.68	5.37	4.68	5.00	5.00	3.68

Year	1,000 pounds 5–7–0	1,000 pounds 5–7–5	1,000 pounds 5–7–7	1,000 pounds 5–7–10	1,000 pounds 5–7–5	1,000 pounds 5–7–6	1,000 pounds 5–7–5	1,000 pounds 5–7–5
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1933	8.25	4.50	5.00	4.00	5.75	7.75	2.75	6.00
1934	1.25	2.00	2.00	2.00	.50	1.00	2.75	1.25
1935	9.00	7.75	10.00	8.75	7.00	8.50	7.25	8.25
1936	8.00	6.25	5.25	6.50	8.25	3.75	5.25	7.25
Mean	6.62	5.12	5.56	5.31	5.37	5.25	4.50	5.68

[1] The formulas indicate percentages of nitrogen, phosphoric acid, and potash, respectively

Table 6 shows the statistical analysis of the data in table 5. Taking the remainder (error) variance as a basis of comparison, the evidence indicates that there are no significant differences in dry root rot between the different treatments. In the case of years, however, it is again apparent that root rot is materially influenced by seasonal differences.

TABLE 6.—*Analysis of variance of data entering into table 5*

Source of variation	Degrees of freedom	Total sum of squares	Mean square	Source of variation	Degrees of freedom	Total sum of squares	Mean square
Total	63	458.23	7.27	Years	3	356.12	118.70
Treatment	15	24.98	[1] 1.66	Remainder	45	77.13	1.71

[1] Not significant with reference to remainder (error).

Considerably more damping-off has been experienced in plots treated with fertilizers containing high percentages of organic nitrogen—that is, nitrogen derived from fish, dried blood, tankage, etc.—

than on those with fertilizers containing only inorganic nitrogen (ammonium salts and nitrates). A series of plots was run with 1,000 pounds per acre of fertilizers containing varying proportions of the nitrogen from organic sources in order to study their effect on dry root rot. All mixtures analyzed 5 percent of nitrogen, 7 percent of phosphoric acid, and 5 percent of potash. Table 7 shows the results of these treatments. Considerable variations occurred between treatments, and the mean amounts of dry root rot for the 4-year period tended to increase as the amount of organic nitrogen increased. However, when the data are analyzed statistically (table 8) it is seen that no significant differences exist between the different treatments. With an F value of 6.88 for years (5 percent point=3.86; 1 percent point=6.99), it is seen that seasonal conditions from one year to another have a much greater influence on root rot development than do the variations in the fertilizers used.

TABLE 7.—*Mean percentage of Stringless Black Valentine bean plants infected with dry root rot when grown in plots treated with fertilizers containing different proportions of nitrogen from organic sources*

Year	Root rot on plots receiving nitrogen from organic sources—				
	None	20 percent	33 percent	50 percent	Mean
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1933	2.0	4.5	6.0	6.5	4.75
1934	3.5	2.0	1.0	5.5	3.00
1935	7.5	8.0	9.5	13.5	9.63
1936	6.0	5.5	4.5	2.0	4.50
Mean	4.7	5.0	5.2	6.9	5.47

TABLE 8.—*Analysis of variance of data entering into table 7*

Source of variation	Degrees of freedom	Total sum of squares	Mean square	Source of variation	Degrees of freedom	Total sum of squares	Mean square
Total	15	155.50	10.3666	Years	3	100.06	33.3533
				Remainder	9	43.63	4.8477
Treatment	3	11.81	[1] 3.9366				

[1] Not significant with reference to remainder (error).

FERTILIZER PLACEMENT

In view of the fact that certain fertilizer materials are known to be toxic to plant root systems when in concentrated form, a series of plots was run over a period of 4 years in order to study the effect of different methods of fertilizer placement on dry root rot development in beans. Using applications of 1,000 pounds per acre in all cases, the placements were as follows:

1. In broad band, thoroughly worked into soil, according to local practice.
2. In broad band, not worked into soil.
3. In narrow band, 6 inches to one side of row.
4. Side-dressed when plants were 4 inches high.

The dry root rot, stand, and yield data for the 4 years of this work are shown in table 9. Considerable differences occurred between treatments during some seasons and very little during others. The means of root rot infection and stand for the 4-year period indicate

that treatments 1 and 2, involving application in the row, may be injurious to the seed or root system, thus facilitating infection by the root rot fungus. The effects of treatment on percentage of dry root rot and on stand were significant, but the effect on dry root rot was quite variable from year to year. (See variances due to treatment, treatment × years, and error in table 10.) Treatment was without significant effect on yield. As in the other fertilizer tests, the differences in conditions of tests between years appear to be more important than the treatments used.

TABLE 9.—*Effect of different methods of fertilizer placement on percentage of Stringless Black Valentine bean plants infected with dry root rot, on stand, and on yield*

[Quintuplicate plots]

DRY ROOT ROT INFECTION

Year	Response to fertilizer placement				
	Local practice	Broad band not stirred	Band 6 inches to one side	Side dressing	Mean [1]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1933	4.8	5.8	4.2	3.6	4.6
1934	19.6	12.4	10.8	6.4	12.3
1935	4.8	9.2	5.2	7.6	6.7
1936	59.2	68.0	35.2	26.4	47.2
Mean [1]	22.1	23.9	13.9	11.0	17.7

PLANTS PER PLOT

	Number	*Number*	*Number*	*Number*	*Number*
1933	211	194	217	224	211
1934	336	297	371	369	343
1935	468	417	418	464	442
1936	204	179	207	226	204
Mean [1]	305	272	303	321	300

YIELD PER PLOT

	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1933	6.50	5.40	6.95	6.60	6.36
1934	16.95	15.50	18.85	16.80	17.03
1935	37.70	35.25	34.75	35.20	35.73
1936	10.30	6.30	8.35	9.70	8.66
Mean [1]	17.86	15.61	17.22	17.07	16.94

[1] Differences required for significance between treatments or between years are: 4.9 percent for dry root rot, 17 plants for stand, and 1.6 pounds for yield.

Despite the significant difference in dry root rot and stand among treatments, tables 9 and 10 indicate that the root rot had no important effect on yield. The coefficients of correlation between root rot and stand and between root rot and yield are of a significant magnitude for total covariance, but it is very doubtful that a causal relationship existed in either case. The more probable explanation is that applying fertilizer heavily in the row injured the seed and seedlings, reducing the stand and making the plants susceptible to infection. If dry root rot seriously affected yield, a negative correlation would be expected for sources of variation other than total, but no such significant values are evident. For error, these correlations are nearly zero despite a wide variation in percentage of dry root rot of the several replicates

within a single treatment and year (not shown); furthermore, the partial correlation for dry root rot and yield with stand held constant becomes a significant positive instead of a negative value for total covariance. This apparent anomaly has already been discussed. It will be also noted that the correlation between stand and yield becomes practically unchanged when the partial correlation is calculated, holding root rot constant.

TABLE 10.—*Analysis of variance and covariance of data entering into table 9*

Source of variation	Degrees of freedom	Mean squares for—			Degrees of freedom	Coefficients of correlation between—			Minimum significant value of r
		Stand	Dry root rot	Yield		Dry root rot and stand	Dry root rot and yield [1]	Stand and yield [2]	
Total	79	10,923.2	429.4	142.9	78	−0.438	−0.316	+0.927	0.217
Between treatments	3	[3] 8,281.4	[3] 779.3	18.1	2	−.795	−.343	+.780	.950
Between years	3	[3] 260,326.7	[3] 11,920.2	[3] 3,555.2	2	−.508	−.392	+.964	.950
Between replicates	4	109.1	62.6	[3] 25.8	3	−.392	−.235	+.407	.878
Treatments × years	9	1,414.9	[3] 439.8	6.1	8	−.088	−.327	+.668	.666
Remainder (error)	60	732.2	58.9	6.8	59	−.088	+.074	+.455	.250

[1] Coefficients of partial correlation between dry root rot and yield with stand held constant are: For total variation, +0.266; for error, +0.129.

[2] Coefficients of partial correlation between stand and yield with dry root rot held constant are: For total variation, +0.924; for error, +0.465.

[3] Significant with reference to error; odds greater than 99:1.

Thus, although the method of fertilizer placement in these studies significantly affected the percentage of plants infected with dry root rot, it had no effect on root rot damage.

DISCUSSION

From the results of different cultural practices studied during a 4-year period at Charleston, S. C., it is apparent that certain practices that may be used by the average grower are more conducive than others to the development of dry root rot in beans. Since crop profits in the South are contingent upon earliness, all growers plant beans as early as weather conditions permit. These data indicate that a greater percentage of plants tend to become infected with root rot on such plantings than if the plantings are made at a later date, although the differences are not significant. An apparent relationship exists between dry root rot infection and initial infections of the root by damping-off fungi, since field readings have shown the latter type of infection to be appreciably greater on early plantings than on those made later in the spring. Beans planted at a depth of 2 inches likewise show more root rot infection than those planted at 1-inch and ½-inch levels. Here again is suggested the relationship of this disease with previous damage to the root systems by damping-off organisms.

There is apparently no correlation between the different types of fertilizers used and infections by the dry root rot organism. Slight differences in infection occurred when various proportions of nitrates from organic sources were used, but these are not significant when considered over a 4-year period.

Different methods of placing fertilizers in the row show considerable differences in amounts of root rot in certain seasons, but no significant differences appear for the whole period of this work.

Throughout all phases of this work, the marked influence of seasonal conditions is strongly emphasized. While any or all of the several cultural methods studied may exert a material influence upon root rot infection in any particular year, seasonal conditions appear to be more important than most of the measures tested.

In these studies there was no appreciable damage by dry root rot despite high percentages of infection in some instances. However, it is reasonable to conclude that in seasons conducive to serious dry root rot damage, more damage will be done if methods that are conducive to the higher percentages of infection are used. Growers will doubtless continue to plant as early as they dare and will take their chances with weather and with dry root rot in the hope of striking good market prices. But it is practicable to plant at optimum depth and to make the proper placement of fertilizer to minimize root rot infection as far as possible.

CONCLUSIONS

Dry root rot of snap beans is widely distributed over the South and varies in severity from season to season.

Dry root rot infection is heavier on beans planted at a 2-inch depth than on those planted at 1-inch and at ½-inch levels.

Beans planted very early in the spring tend to show more dry root rot than those planted at later dates.

The various types of fertilizers studied do not consistently affect dry root rot infection. The placements of fertilizers studied in this work significantly influenced dry root rot infection of beans in certain seasons, but showed no yield differences.

Differences in weather and perhaps other uncontrolled or unidentified factors from year to year produced the greatest differences in dry root rot development during the course of these studies.

It is reasonable to assume that practices which tend to lessen dry root rot infection will, in years favorable to damage, result in less crop loss than practices conducive to heavy infection.

In these particular studies the degree of dry root rot development that was observed appeared to have no significant effect on yield.

RELATIVE RESISTANCE OR SUSCEPTIBILITY OF SNAP BEAN VARIETIES TO MOSAIC AND DRY ROOT ROT AND THEIR EFFECT ON YIELD

A large acreage of snap beans is grown throughout the South, but little information is available on the susceptibility or resistance of the different varieties to mosaic and dry root rot under different local conditions. While a large number of varieties are grown for various local purposes, only a few are grown commercially. In order to determine the response of the better-known commercial varieties to disease, 26 varieties were grown from 1932 to 1936, inclusive. The varieties were grown under average field conditions, and the data presented herein are believed to be typical of the varietal reactions under South Atlantic conditions.

Numerous references in the literature attest to the wide variation among bean varieties in resistance to mosaic and dry root rot. Burkholder (*2*) suggests the use of resistant varieties as one means of controlling dry root rot (*Fusarium martii phaseoli*). McRostie (*14*) found that certain of his hybrid material showed considerable resistance to both root rot and mosaic. Striking differences in resistance to root rot were found in certain field varieties in Idaho

(*10*, *11*). Reddick (*17*) and Reddick and Stewart (*18*) report decided differences in resistance to mosaic among various varieties, while Parker (*15*) and Reddick (*16*, *17*) show that resistance may be developed through plant breeding. Harter and Zaumeyer (*8*) give a list of bean varieties with their relative resistance to mosaic. Thus it is seen that the selection of disease-resistant varieties becomes an important consideration in any scheme of commercial bean production.

MATERIALS AND METHODS

Western-grown seed was used throughout this work, all varieties being planted in 100-foot rows. Owing to limited space in some years, replications varied from one to three. All disease data are presented on the basis of percentage of infection for each year. Counts for dry root rot and mosaic were made just before first bloom. Yield records were taken as the pods developed to marketable size.

RESULTS

MOSAIC

The data on mosaic for the 26 varieties for the 5-year period are shown in table 11, from which it is seen that few varieties show a high percentage of infection. Considerable variation from the general yearly tendency occurs from year to year, which suggests that seed lots of some varieties were more heavily infected in some seasons than in others. The statistical analysis of these data is shown in table 14. Using remainder (error) variance as a basis for comparison, it is seen that significant differences in mosaic infection occur between varieties and also between years. It is apparent that there is a statistically significant difference in susceptibility between Hodson Wax and all other varieties except Red Valentine, and also between Red Valentine and 15 of the 25 other varieties. Significant differences between varieties appeared in 1932, but for the 5-year period, with the exceptions just noted, there were no very significant differences. It is interesting to note that the commercial varieties generally grown in the South show very small amounts of mosaic.

DRY ROOT ROT

The data on dry root rot for all varieties are presented in table 12. A relatively large amount of root rot infection appeared on practically all of the varieties, although considerable variation between varieties is shown. Also, considerable variation is shown from one year to another, which suggests the influence of weather conditions on the development of this disease. The statistical analysis of these data is shown in table 14. Significant differences in root rot infection exist among varieties, but seasonal and test conditions from year to year are the source of much greater variation.

By applying the calculated difference required for significance between means of varieties, it is found that Wardwell Kidney Wax, the most susceptible of all, is significantly more susceptible to dry root rot than 20 of the 25 other varieties, the exceptions being Improved Golden Wax, Round Pod Kidney Wax, Davis White Wax, Keeney Rustless Wax, and Refugee Wax. The lowest infection was shown by Longfellow and Asgrow Stringless Valentine, but they were significantly less susceptible than only 5 of the 12 wax varieties tested and none of the green varieties.

TABLE 11.—*Percentages of bean mosaic infection on 26 varieties in each of 5 years*

Class and variety	Mosaic infection					
	1932	1933	1934	1935	1936	Mean [1]
Green:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Asgrow Stringless Valentine	0.3	0.3	0.4	0.6	0.0	0.3
Black Valentine	4.5	0	0	2.7	1.0	1.6
Bountiful	.9	11.2	.2	1.5	0	2.7
Burpee Stringless Green Pod	0	.4	.4	1.5	0	.4
Dwarf Horticultural	27.9	2.2	.5	3.7	1.3	7.1
Extra Early Refugee	3.3	.3	1.9	9.4	.3	3.0
French Horticultural	18.4	.3	.4	3.7	1.2	4.8
Full Measure	.3	4.9	0	3.1	.3	1.7
Giant Stringless Green Pod	3.6	0	0	.5	0	.8
Konserva	1.6	.5	.4	5.8	0	1.6
Longfellow	4.6	.5	.6	5.1	0	2.1
Lows Champion Bush	10.0	2.1	2.0	5.3	1.1	4.1
Red Valentine	28.8	7.9	.7	6.5	0	8.7
Tennessee Green Pod	7.8	5.7	1.2	1.4	0	3.2
Wax:						
Davis White	5.7	0	.3	1.3	0	1.4
Hodson	53.4	5.0	3.1	7.1	3.8	14.4
Improved Black	4.3	0	0	1.1	0	1.0
Improved Golden	19.7	3.2	.5	5.4	0	5.7
Keeney Rustless	14.8	0	10.8	3.3	0	5.7
Pencil Pod Black	1.2	0	0	1.2	0	.4
Refugee	3.2	.5	.5	11.1	1.0	3.2
Round Pod Kidney	1.1	0	1.2	.6	0	.5
Stringless Kidney	1.9	0	0	1.3	0	.6
Sure Crop Black	4.0	0	.3	1.8	0	1.2
Unrivalled	0	0	0	.1	0	0
Wardwell Kidney	3.5	0	.4	2.1	0	1.1

[1] Difference required for significance between varieties is 6.4 percent.

TABLE 12.—*Percentage of bean dry root rot infection on 26 varieties in each of 5 years*

Class and variety	Dry root rot infection					
	1932	1933	1934	1935	1936	Mean [1]
Green:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Asgrow Stringless Valentine	5.9	8.0	13.0	2.1	0.5	5.9
Black Valentine	.5	3.7	23.0	.7	4.0	6.4
Bountiful	7.0	9.6	11.0	.0	3.5	6.2
Burpee Stringless Green Pod	3.0	7.4	21.0	1.4	4.5	7.5
Dwarf Horticultural	6.0	3.8	26.0	2.8	6.5	9.0
Extra Early Refugee	14.0	16.0	27.0	2.6	2.0	12.3
French Horticultural	6.0	5.0	26.0	13.3	5.5	11.2
Full Measure	5.3	6.1	17.0	1.8	4.0	6.8
Giant Stringless Green Pod	19.0	7.5	11.0	2.9	2.5	8.6
Konserva	12.0	21.6	22.0	4.6	0	12.0
Longfellow	0	6.1	19.0	3.3	1.0	5.9
Lows Champion Bush	25.0	2.3	36.0	3.3	7.5	14.8
Red Valentine	5.5	9.7	21.0	1.7	4.5	8.5
Tennessee Green Pod	9.0	12.2	29.0	0	2.0	10.4
Wax:						
Davis White	7.9	32.3	44.0	6.8	3.5	18.9
Hodson	9.0	1.2	22.0	2.8	2.5	7.5
Improved Black	12.0	2.0	27.0	2.0	2.0	9.0
Improved Golden	2.0	30.5	50.0	2.7	3.0	17.6
Keeney Rustless	24.0	2.0	50.0	4.4	8.0	17.7
Pencil Pod Black	3.3	17.1	14.0	3.7	2.0	8.0
Refugee	15.8	1.1	56.0	2.7	3.5	15.8
Round Pod Kidney	16.6	33.0	32.0	4.4	2.5	17.7
Stringless Kidney	14.0	.2	44.0	8.8	3.0	14.0
Sure Crop Black	2.0	13.7	17.0	0	1.5	6.8
Unrivalled	14.6	12.5	34.0	4.1	4.5	13.9
Wardwell Kidney	11.5	54.0	48.0	9.5	8.5	26.3

[1] Difference required for significance between varieties is 10.9 percent.

YIELDS

Wide variations in yield occurred (table 13), the French Horticultural variety producing the smallest yield and the Round Pod Kidney

Wax the largest. In the green pod group, Bountiful, Full Measure, Tennessee Green Pod, Asgrow Stringless Valentine, and Konserva gave the best yields. Bountiful, Asgrow Stringless Valentine, Burpee Stringless Green Pod, and Giant Stringless Green Pod are the most popular varieties grown in the South.

The statistical analysis of the above data is given in table 14, from which it is seen that significant differences in yields occurred between varieties and also that wide variations are shown from one season to another. In view of the fact that these differences in yields are based upon the results of actual field conditions, the limiting influence of both mosaic and root rot infections should be considered.

TABLE 13.—*Yields of 26 varieties of snap beans in each of 5 years*

Class and variety	Yield per plot					
	1932	1933	1934	1935	1936	Mean [1]
Green:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Asgrow Stringless Valentine	45.01	39.15	88.8	45.52	6.60	45.0
Black Valentine	15.72	40.02	42.8	38.68	5.72	28.6
Bountiful	41.86	48.25	83.6	61.46	26.76	52.4
Burpee Stringless Green Pod	37.06	38.76	71.2	40.32	6.46	38.8
Dwarf Horticultural	44.24	43.35	47.6	38.96	15.34	37.9
Extra Early Refugee	25.80	23.60	74.0	39.45	13.37	35.2
French Horticultural	2.82	15.70	31.2	31.94	20.41	20.4
Full Measure	51.82	49.25	81.8	50.30	12.29	49.1
Giant Stringless Green Pod	30.20	43.90	59.4	43.79	16.86	38.8
Konserva	54.01	45.80	48.8	26.76	94.70	54.0
Longfellow	24.20	50.50	78.6	43.52	16.22	42.6
Lows Champion Bush	26.96	29.90	50.8	33.42	12.66	30.8
Red Valentine	35.26	42.40	58.2	53.25	27.62	43.3
Tennessee Green Pod	23.26	55.20	118.8	44.42	12.45	50.8
Wax:						
Davis White	39.08	44.45	82.2	49.10	92.83	61.5
Hodson	26.30	9.65	35.4	33.48	24.41	25.8
Improved Black	29.78	23.60	63.8	46.55	40.93	40.9
Improved Golden	20.30	32.15	61.4	41.94	29.48	37.1
Keeney Rustless	28.08	15.80	28.2	30.89	38.94	28.4
Pencil Pod Black	34.00	20.25	59.0	51.28	20.75	37.1
Refugee	18.10	22.40	38.6	26.57	18.25	24.8
Round Pod Kidney	22.98	40.50	78.2	55.40	163.52	72.1
Stringless Kidney	20.76	38.80	59.2	40.44	39.80	39.8
Sure Crop Black	50.70	39.60	75.8	59.74	22.16	49.6
Unrivalled	19.20	45.75	52.2	44.61	5.95	33.5
Wardwell Kidney	21.94	29.90	78.6	38.68	51.66	44.2

[1] Difference required for significance between varieties is 23.4 pounds.

TABLE 14.—*Analysis of variance and covariance of mosaic (M), dry root rot (R), and yield (Y) data of 26 varieties of beans shown in tables 11, 12, and 13, respectively*

Source of variation	Degrees of freedom	Mean squares for—			Degrees of freedom	Coefficients of correlation			Minimum significant correlation
		Mosaic	Dry root rot	Yield		*MR*	*RY* [1]	*MY* [2]	
Total	129	42.57	160.93	545.66	128	−0.071	+0.253	−0.158	0.174
Between varieties	25	[3] 69.42	[4] 133.76	[3] 688.67	24	−.066	+.099	−.348	.388
Between years	4	[3] 289.29	[3] 2,477.59	[3] 4,714.19	3	−.181	+.870	−.415	.878
Remainder (error)	100	25.99	75.06	343.17	99	−.003	−.177	+.099	.195

[1] Coefficients of partial correlation between dry root rot and yield with mosaic held constant are: For total variation, +0.246; between varieties, +0.081; for error, −0.178.

[2] Coefficients of partial correlation between mosaic and yield with dry root rot held constant are: For total variation, −0.145; between varieties, −0.343; error, +0.101.

[3] Significant by odds greater than 99:1.

[4] Significant by odds greater than 19:1 but less than 99:1.

The correlations between dry root rot infection and yield and between mosaic and yield, shown in table 14, are of particular interest. In only one case is a significant coefficient shown—that between dry root rot and yield for total covariance; and, as has been shown previously in this bulletin, the correlation is positive instead of negative as might be expected. It can hardly be concluded, however, that dry root rot infection is beneficial. Covariance between varieties shows a nearly zero coefficient. With reference to mosaic and yield, all coefficients are insignificant, but negative as one would expect. The coefficient for covariance between varieties approaches significance, but does not attain it. There is no tendency for susceptibility to mosaic and to dry root rot to be associated either positively or negatively among these varieties as observed in these studies. The coefficients of partial correlation between dry root rot and yield and between mosaic and yield, holding constant the third variable, are almost identical with the respective simple correlations.

DISCUSSION

From the data compiled for the several varieties grown in this experiment, it appears that few show enough mosaic for the disease to be considered of commercial importance in the spring crop in the South Atlantic area. While some varieties showed fairly high percentages of the disease in certain years, the means for the 5-year period show relatively small amounts of mosaic. It is apparent, however, that Hodson Wax and Red Valentine are significantly more susceptible to this disease than most of the others. It is rather surprising that the Refugee types showed no more serious infection by mosaic, since they are generally considered to be among the most susceptible varieties that are grown extensively.

Considerable difference among varieties was found in susceptibility to infection by dry root rot, ranging from 5.9 for the Asgrow Stringless Valentine and the Longfellow to 26.3 for Wardwell Kidney Wax. It is interesting to note that most of the varieties that are closely related to the old Black Valentine variety show fairly good resistance to dry root rot infection, whereas the majority of the wax varieties observed were rather susceptible.

CONCLUSIONS

Among 26 varieties of snap beans tested, significant differences were found between varieties in susceptibility to mosaic and to dry root rot infection and in yield.

In these studies neither mosaic nor dry root rot damage appeared to be responsible for yield differences.

Wide differences occurred in yields between varieties, many of them being highly significant and apparently due to varietal characteristics or regional adaptation other than resistance or susceptibility to mosaic and dry root rot.

Highly significant differences in mosaic infection, dry root rot infection, and in yields occur from one season to another.

CONTROL OF DAMPING-OFF OF BEANS BY SEED TREATMENT

Since the principal acreage of snap beans in the southeastern United States is grown for the early northern market, the planting period varies from October in southern Florida to early April in coastal Virginia. During this time the soil temperatures are somewhat low,

rainfall is comparatively high in some localities, and as a result considerable damage is experienced by growers from poor stands and weak plants, owing to infections by various soil-borne fungi. In many instances entire fields have been lost, while in others only partial stands have been obtained (fig. 1). On farms where good stands emerge,

FIGURE 1.—*A*, Field of snap beans showing poor stand due to damping-off; *B*, section of same field showing an even stand.

numerous plants are invariably found that show a weakened condition as a result of fungus infection of the root system. As a part of a study of the nature of this trouble, together with a study of possible methods of control, seed-treatment experiments were started at Charleston, S. C., in 1931 and continued through 1935.

Root rot damage on beans, caused by several different organisms, is reported from practically every section where this crop is grown. However, reports are given in only a few instances of conditions similar to those encountered in the present studies. Cook (*5*) reported

briefly a damping-off of young bean plants in New Jersey which occurs under warm wet conditions. No specific causal organism was named in connection with this disease. Burkholder (*2*, *3*) reported in detail a root rot caused by *Fusarium martii phaseoli*, but states that it is more active during dry seasons than in those of considerable rainfall. Mackie (*13*) described a new root rot disease of beans in California, caused by *Rhizoctonia bataticola* (Taubenhaus) Butler, and Kendrick (*12*) showed that the organism is most active at temperatures of about 80° F. Weimer and Harter (*23*) also found a root rot disease in California in which was involved *F. martii phaseoli*, and also a new species, *F. aduncisporum* Weimer and Harter. Other soil organisms that have been associated with the various bean root rots are species of *Sclero-*

FIGURE 2.—*A*, Young bean plants. Two plants at right show destruction of root system and stunted growth; two normal plants at left. *B*, Bean plants at advanced stage of growth. Plant at right badly infected with *Pythium debaryanum;* normal plant at left. Note in the former lateral roots above infected area which support plant life.

tinia and *Sclerotium rolfsii* Sacc. In most cases, however, the rots produced by these several organisms are characterized by stem discolorations, stem lesions, or girdling of the plant near the soil line. Little or no damage has been reported from loss of stands during the period of germination or from a general weakening of the plants through an infection of the entire root system.

DESCRIPTION OF THE DISEASE

Damping-off, as it occurs in the South, may attack the young seedling at any time from the beginning of germination until after the plant emerges from the soil and the first trifoliate leaves are formed. In some instances the seedlings are destroyed prior to emergence, while in others they are killed after showing above ground. In the case of plants that emerge normally, a large percentage show a damping-off of the lateral roots (fig. 2) which does not kill the plants but retards further development to a marked degree. This is particularly true

where the root system is near the soil surface, thus preventing growth of new laterals higher on the main stem. Such plants fail to set a full crop of beans, and the quality of the pods formed is usually poor.

CAUSAL ORGANISM

The organism most commonly associated with damping-off of beans in the Southeast is *Pythium debaryanum* Hesse. It is found in all soil types and is particularly destructive during early spring when there is an abundance of soil moisture and when soil temperatures are somewhat low. Infected bean roots have been found at all times during the growing season, but it is only in early spring that plants are actually killed.

MATERIALS AND METHODS

In view of the fact that bean seeds are difficult to treat with liquids without injuring them, dust treatments were used throughout this work with the exception of corrosive sublimate solution 1:1,000. This was used as a 10-minute soak and was introduced particularly to test the effect of surface sterilization upon germination and early growth. All other lots of seed were treated at the rate of 3 ounces of dust per bushel of seed, the dust being applied by agitating the seed and dust in a tightly closed container for 5 minutes. Equal quantities of seed were planted in 100-foot rows and replicated three times. Three plantings were made each season, the first as early in March as weather conditions would permit, and the second and third at intervals of approximately 2 weeks. Stand counts were made when the second trifoliate leaves were forming. In many cases the chemicals showed no beneficial results or else were so injurious to germination that they were discontinued after one season. By eliminating all unpromising materials as they were discovered, only three preparations (chlorophenol mercury 30 percent and two concentrations of ethyl mercury tartrate) were found worthy of continued use throughout the 5-year period. The various materials tested were:

Mercuric chloride 1: 1,000
Ethyl mercury tartrate 1 percent (952–H)
Ethyl mercury tartrate 2 percent (952–BB)
Chlorophenol mercury 30 percent (Semesan)
Copper oxide 100 percent
Mercuric iodide 100 percent
Yellow oxide of mercury 100 percent
Mercurous chloride 100 percent
Mercurous chloride 50 percent in clay
Mercuric chloride 50 percent in clay
Formaldehyde dust 6 percent
Copper tartrate 100 percent
Ethanol mercury chloride 7.9 percent
Mercuric salicylate 5 percent
Mercury naphtholate 6 percent
Copper carbonate 18 percent
Copper carbonate 50 percent
Copper phosphate 14 percent

Yield records were taken as the pods developed to marketable size, the yields being recorded in pounds. In several instances the third planting was damaged by weather conditions to such an extent that no yield records were taken, consequently yield data were tabulated for only the first and second plantings throughout the 5-year period.

RESULTS

The stand data are shown in table 15 for the 5-year period. The mean stands for the 952–BB treatment were consistently better than the untreated check in all years for the first planting. This treatment gave better stands than the untreated check in 4 of the 5 years in both

the second and the third plantings. The 952–H treatment gave essentially the same results as 952–BB. Semesan failed to show beneficial results, in general having a depressive effect. The reason the treatments showed more striking results in the earlier plantings than in the later ones may be found in the temperature data shown in table 17. Here it is noted that the mean soil temperature rose rapidly each year from the time of the first planting to the date of the subsequent one. Hemmi (*9*) found that *Pythium debaryanum* was more active against garden cress at temperatures between 20° and 30° C., whereas Richards (*20*) showed the optimum range for *Corticium vagum* Berk. and Curt. to be from 9° to 29°. On the basis of the data at hand it is apparent that the bean seedlings in the first plantings were subject to a more active fungus attack at the lower temperature range than when planted at a later date.

TABLE 15.—*Relation of seed treatment of Stringless Black Valentine* [1] *bean to stand per plot*

[Triplicate plots]

Planting and year	Stand of plants in response to treatment—				
	Semesan	952–H	952–BB	Check	Mean
First:	*Number*	*Number*	*Number*	*Number*	*Number*
1931	315	313	320	315	316
1932	193	301	303	198	248
1933	289	249	256	221	254
1934	331	454	460	358	401
1935	433	586	567	538	531
Mean [2]	312	381	381	326	350
Second:					
1931	349	343	345	340	342
1932	278	351	393	313	334
1933	198	371	311	319	300
1934	344	445	478	472	435
1935	418	497	513	505	484
Mean [2]	317	401	406	390	379
Third:					
1931	344	343	349	340	344
1932	230	329	312	301	293
1933	211	359	298	265	283
1934	334	399	389	444	392
1935	407	505	457	453	459
Mean [2]	305	387	361	360	354
Mean, first and second plantings [3]	315	391	395	358	365
Mean, all three plantings [4]	312	390	383	359	361

[1] Bountiful instead of Stringless Black Valentine was grown in 1932.
[2] Difference required for significance between treatments within a planting is 24 plants.
[3] Difference required for significance between treatments for two plantings is 22 plants (see table 18).
[4] Difference required for significance between treatments of all plantings is 14 plants.

The variance analysis of the 5-year results of the above treatments and their effect on stand is given in table 16. Using the remainder (error) variance as a basis of comparison with treatments, years, and plantings, highly significant differences are indicated in each of these cases. The greatest differences were between years. This is not surprising, since, as shown in table 17, environmental condition in some years were much more favorable for fungus activity than in others. When plantings are considered as a source of variance, significant differences are shown. Here again the influence of weather conditions is seen, since the rising soil temperatures at the later dates

of planting made seed treatment less necessary for obtaining a full stand. Semesan was the least satisfactory of any of the organic mercury compounds used. Under most conditions its use was associated with some reduction in stand in comparison with the untreated check. Of the three compounds used throughout the 5-year period, 952–BB (2 percent ethyl mercury tartrate) gave the consistently best results compared with the check, although it was not significantly better than 952–H (1 percent ethyl mercury tartrate) as measured by the required difference of 14 plants at the end of the 5-year period. The actual differences for 952–H, 952–BB, and Semesan when compared with the check were +31, +25, and −47, respectively. From these figures it is seen that Semesan was injurious to stand as a treatment material when considered for the entire 5-year period.

TABLE 16.—*Analysis of variance and covariance for data entering into table 15*

Source of variation	Degrees of freedom [1]	Mean squares for stand (table 15)	Source of variation	Degrees of freedom [1]	Mean squares for stand (table 15)
Total	176	9,992.05	Between replicates	2	[2] 2,062.51
			Treatments × plantings	6	19,851.95
Between treatments	3	23,815.14	Treatments × years	12	13,597.21
Between years	4	284,333.71	Years × planting	8	9,745.94
Between plantings	2	14,706.29	Remainder (error)	139	1,122.57

[1] Degrees of freedom 3 less than normal to make allowance for 3 calculated values in the table.
[2] Not significant with reference to error. All other variances significant by odds greater than 99:1.

TABLE 17.—*Total rainfall and mean temperatures at Charleston, S. C., for 20 days following each of three planting dates*

Year	After first planting		After second planting		After third planting	
	Rainfall	Mean temperature	Rainfall	Mean temperature	Rainfall	Mean temperature
	Inches	° *F.*	*Inches*	° *F.*	*Inches*	° *F.*
1931	1.21	50.1	1.86	53.3	2.19	55.9
1932	2.58	51.0	.67	62.8	.27	66.6
1933	.30	62.0	1.23	62.8	1.35	65.4
1934	.48	54.0	.82	61.6	1.54	66.1
1935	.90	63.8	.83	67.1	.16	64.0

All of the interaction variances given are significant in comparison with the error variance. The significance of variances for years, plantings, and interactions indicates that differences in environment may be of much greater influence on stand than the treatments used, and also that the treatments must be considered in relation to the environmental conditions under which they are being used.

The yield data for the 5-year period are shown in table 18 and the analysis of variance in table 19. There were no significant differences in yield due to treatment or to any interaction involving treatment (table 19).

Despite the slightly better stands for the second plantings than for the first, the first plantings rather consistently and significantly outyielded the second. It is interesting to note that the 5-year mean check yields were nearly identical for the two plantings. It might seem that the treatments were associated with the lower yields of the second planting, but such a conclusion is hardly justifiable, because

the interaction between treatment and planting is not significant. This situation is probably due to merely a chance relatively high mean check yield for the second planting. The yields were rather inconsistent between plantings within years and treatments.

TABLE 18.—*Relation of seed treatment of Stringless Black Valentine[1] beans to yield per plot*

[Triplicate plots]

Planting and year	Yield per plot in response to treatment				
	Semesan	952–H	952–BB	Check	Mean
First:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1931	14.2	10.8	10.6	12.8	12.1
1932	6.8	7.8	7.5	6.4	7.1
1933	34.4	29.8	30.2	23.7	29.5
1934	27.2	28.6	33.8	26.0	28.9
1935	48.5	55.3	55.9	56.5	54.1
Mean	26.2	26.4	27.6	25.1	26.3
Second:					
1931	13.9	10.8	10.8	14.5	12.5
1932	7.8	12.1	12.0	13.0	11.2
1933	20.0	21.7	23.9	32.9	24.6
1934	21.8	30.2	27.2	24.8	26.0
1935	30.1	33.9	36.0	37.8	34.4
Mean	18.7	21.7	22.0	24.6	21.7
Mean of 2 plantings	22.4	24.1	24.8	24.8	24.0

[1] Bountiful instead of Stringless Black Valentine was grown in 1932.

TABLE 19.—*Analysis of variance and covariance of data for first and second plantings shown in tables 15 and 18*

Source of variation	Degrees of freedom [1]	Mean squares for—		Coefficients of correlation, stand × yield
		Stand	Yield	
Total	117	11,401.20	225.43	[2] +0.650
Between treatments	3	[2] 40,775.89	37.05	+.248
Between years	4	[2] 225,860.86	[2] 4,733.98	+.780
Between plantings	1	[2] 24,768.13	[2] 627.01	
Between replicates	2	1,181.27	103.72	−.863
Treatment × planting	3	[3] 4,662.60	66.02	[3] +.985
Treatment × years	12	[2] 5,056.17	30.59	[2] +.752
Years × planting	4	[2] 14,074.44	[2] 494.73	[3] +.927
(Years × planting × treatment) [4]	(12)	[2] (4,077.08)	(29.71)	+.388
Remainder (error)	88	1,705.44	44.88	+.152
(Remainder error)	(76)	(1,330.97)	(47.28)	(+.109)

[1] Degrees of freedom for coefficients of correlation are 1 less than each value shown for variance. Allowance has been made for 2 derived values in the tables.
[2] Significant by odds greater than 99 : 1.
[3] Significant by odds greater than 19 : 1 but less than 99 : 1.
[4] Data in parentheses are presented as part of an alternate or additional analysis of the data. (See text, p. 19.)

If the interaction of years × plantings × treatments is calculated and a new remainder error obtained (see values in parentheses in table 19), it will be seen that the interaction is smaller than the error. Thus, treatments have failed to show significantly different yields even within different plantings and years. However, years × planting shows a variance that is significantly greater than years × planting

× treatments, further indicating the minor part played by treatment. (Observed $F = 16.6$; 1 percent point = 4.22.)

A study of table 17 in connection with table 18 suggests a close relationship between weather and yield among seasons and between planting. However, there appears to be no safe basis for an explanation of the interactions involving treatment.

CONCLUSIONS

Stands were depressed slightly but significantly by Semesan seed treatment, and were improved by ethyl mercury tartrate treatment; but yields were not significantly affected by any treatment.

Although there are unexplained exceptions, it appears that in general the successful treatments are of more benefit to early than to the later plantings, which encounter warmer and less rainy weather and are therefore less liable to infection. They are generally more beneficial in cool, wet years than in warmer, less rainy years.

EFFECT OF BEAN MOSAIC ON YIELD, POD LENGTH, AND POD WEIGHT

Bean mosaic is widely distributed throughout the South, varying in importance from one season to another and with the susceptibility of the variety grown. Since this disease is considered to be less important in this region than bacterial leaf spot, mildew, or dry root rot, little attention has been given to its direct effect on yield and marketable quality of pods. In order to study these effects of the disease, investigations involving two plantings per season were made in 1935 and 1936.

While the mosaic disease of beans has been known for many years and numerous reports have been made on the characteristics of the trouble, few records are available that give detailed information on the nature and amount of the losses. Clinton (*4*) reported a chlorosis of beans in Connecticut in 1908 which apparently caused some losses. The disease was reported as being serious on navy beans in Michigan the same season.[5] Barss (*1*) found infections as high as 50 percent in Oregon in 1917. The Plant Disease Reporter for 1925 to 1927 [6] ranked mosaic next to bacterial blight as a disease destructive to the bean crop. Fajardo (*6*) gave considerable data on the effect of the disease on yields, showing that early infected plants may yield no pods at all, whereas those infected just prior to blooming may yield from 30 to 50 percent less than those infected after blooming. Harrison (*7*) likewise reported reduced yields, pods of poor quality, and delayed maturity from mosaic infection.

PROCEDURE

The varieties Refugee 1000 to 1 and Early Refugee were used throughout this study because of their susceptibility to mosaic. Plantings were made in March and September in 1935 and 1936. At the time of formation of the first trifoliate leaves a number of mosaic-infected plants were staked in each row, and near each of them a companion disease-free plant was staked. The plots were inspected at frequent intervals, and all plants that were disease-free at the time of staking the early infected plants were removed if they later showed

[5] UNITED STATES BUREAU OF PLANT INDUSTRY. REPORT ON BEAN DISEASES. U. S. Bur. Plant Indus. Plant Disease Bull. 2: 262. 1918. [Mimeographed.]

[6] UNITED STATES BUREAU OF PLANT INDUSTRY. [REPORTS ON BEAN DISEASES.] U. S. Bur. Plant Indus. Plant Disease Rptr. Sup. 1–64. 1919–28. [Mimeographed.]

infection. Along with these were removed also the companion plants that developed mosaic, thereby maintaining the same number of diseased and disease-free plants for record in each row throughout the season. First harvesttimes were based on the marketable size of the pods on the disease-free plants. Both healthy and diseased plants were harvested individually, the number of pods, length of pods, and weight of pods being recorded for each. Weather conditions permitted only two harvests in the fall plantings of the Refugee 1000 to 1 variety and three of the Early Refugee variety.

RESULTS

The data for the four crops of both varieties are shown in table 20. In all cases except one, yields of Refugee 1000 to 1 were decreased to a marked degree by mosaic on the first and second harvest dates. This effect appears to be due partly to delayed plant development and partly to smaller sets of pods. With reference to pod length and pod weight, pods from diseased plants were inferior in one or both respects to those from mosaic-free plants in all cases but one, showing the definite limiting effect of mosaic on growth. The total lengths of the pods harvested from diseased plants were consistently less than those from disease-free plants, further suggesting a decreased quality and market value of the harvested products. Most of the differences in yield, however, were due to differences in number of pods per plant.

The averages of yields, pod lengths, pod numbers, and single pod weights for the infected plants, expressed as percentage of the corresponding healthy plants, are shown in table 21. This summary shows that the spring crops were damaged relatively less than the fall crops—21 and 23 percent lower yield as compared with 42 and 50 for the respective varieties.

Table 22 presents the analyses of variance of the data appearing in table 20 and has a direct bearing on the derived figures shown in table 21. It should be borne in mind that these analyses were worked out upon the single-picking basis and so must be interpreted with that fact in mind. Analyses based on total yields alone will be mentioned subsequently.

TABLE 20.—*Relation of early mosaic infection to yield and number of pods per plant and to individual pod length and weight*

REFUGEE 1000 TO 1

Crop and order of harvest	Condition of plants	Yield per plant	Pods per plant	Mean length of pods	Mean weight of pods
Spring, 1935:		*Grams*	*Number*	*Centimeters*	*Grams*
1	Mosaic	9.6	2.5	9.2	3.8
	Healthy	14.8	3.7	9.3	4.0
2	Mosaic	17.1	3.4	10.0	4.3
	Healthy	23.7	5.3	10.3	4.5
3	Mosaic	55.9	12.3	9.9	4.4
	Healthy	64.0	14.1	12.7	4.5
4	Mosaic	37.3	11.0	9.4	3.4
	Healthy	47.1	13.1	9.7	3.5
Total [1]	Mosaic	119.9	29.2	9.6	3.9
	Healthy	149.6	36.2	10.9	4.1

Footnote at end of table.

TABLE 20.—*Relation of early mosaic infection to yield and number of pods per plant and to individual pod length and weight*—Continued

REFUGEE 1000 TO 1—Continued

Crop and order of harvest	Condition of plants	Yield per plant	Pods per plant	Mean length of pods	Mean weight of pods
		Grams	*Number*	*Centimeters*	*Grams*
Spring, 1936:					
1	Mosaic	13.7	3.7	9.2	3.7
	Healthy	42.9	10.5	9.2	4.1
2	Mosaic	14.5	3.5	9.1	4.2
	Healthy	33.9	7.1	9.2	4.8
3	Mosaic	19.2	4.9	8.9	3.9
	Healthy	13.6	3.1	9.0	4.4
4	Mosaic	19.2	5.4	8.4	3.6
	Healthy	5.3	1.3	8.4	4.0
Total [1]	Mosaic	66.6	17.5	8.8	3.8
	Healthy	95.7	22.0	9.2	4.4
Fall, 1935:					
1	Mosaic	1.5	.5	8.6	3.0
	Healthy	15.2	3.6	9.9	4.2
2	Mosaic	16.3	4.5	9.3	3.7
	Healthy	23.1	5.4	9.8	4.3
Total [1]	Mosaic	17.8	5.0	9.2	3.6
	Healthy	38.3	9.0	9.8	4.3
Fall, 1936:					
1	Mosaic	9.4	2.8	9.2	3.4
	Healthy	26.7	8.6	10.2	3.1
2	Mosaic	12.4	4.1	8.6	3.0
	Healthy	10.2	3.1	9.0	3.4
Total [1]	Mosaic	21.8	6.9	8.9	3.2
	Healthy	36.9	11.7	9.9	3.2

EARLY REFUGEE

Spring, 1935:					
1	Mosaic	17.9	5.0	8.4	3.5
	Healthy	31.0	8.5	8.5	3.7
2	Mosaic	42.4	13.4	7.1	3.2
	Healthy	54.1	15.7	7.6	3.5
3	Mosaic	25.4	6.5	7.0	3.9
	Healthy	31.4	7.5	7.6	4.2
4	Mosaic	23.9	5.8	7.6	4.1
	Healthy	18.0	3.8	8.3	4.7
Total [1]	Mosaic	109.6	30.7	7.4	3.6
	Healthy	134.5	35.5	7.9	3.8
Spring, 1936:					
1	Mosaic	24.4	6.7	8.4	3.7
	Healthy	44.3	10.3	8.8	4.3
2	Mosaic	16.7	4.6	7.3	3.7
	Healthy	26.3	7.0	7.7	3.8
3	Mosaic	21.8	6.4	6.9	3.4
	Healthy	26.6	6.8	7.6	4.0
4	Mosaic	11.0	2.6	7.2	4.3
	Healthy	15.2	3.0	8.3	5.1
Total [1]	Mosaic	73.9	20.3	7.5	3.7
	Healthy	112.4	27.1	8.2	4.2
Fall, 1935:					
1	Mosaic	10.4	3.1	8.3	3.3
	Healthy	34.0	8.0	9.0	4.3
2	Mosaic	12.5	3.6	8.0	3.5
	Healthy	17.5	4.7	8.9	3.7
3	Mosaic	19.5	5.1	8.1	3.8
	Healthy	18.8	4.5	8.2	4.2
Total [1]	Mosaic	42.4	11.8	8.1	3.6
	Healthy	70.3	17.2	8.6	4.1
Fall, 1936:					
1	Mosaic	15.2	3.9	8.6	3.9
	Healthy	38.6	8.7	9.0	4.3
2	Mosaic	10.6	3.2	6.9	3.3
	Healthy	12.0	3.1	7.8	4.0
3	Mosaic	7.5	3.7	6.5	2.0
	Healthy	13.4	4.0	6.9	3.4
Total [1]	Mosaic	33.3	10.8	7.3	3.1
	Healthy	64.0	15.8	8.2	4.0

[1] Total figures for yield per plant and pods per plant are sums of the 2, 3, or 4 harvests for each crop. The corresponding figures for the last 2 columns are weighted means of the several individual harvests contributing to the totals.

TABLE 21.—*Yield and number of pods per plant, pod lengths, and individual pod weights from mosaic-infected plants expressed as percentage of healthy plants*

[Data calculated from those in table 20]

COMBINED SPRING CROPS OF 1935 AND 1936

Variety and order of harvest	Yield per plant	Number of pods per plant	Mean length of pods	Mean weight of pods
	Percent	*Percent*	*Percent*	*Percent*
Refugee 1000 to 1:				
1	48	51	99	94
2	62	67	97	94
3	91	96	79	95
4	92	94	96	96
Total [1]	77	83	90	94
Early Refugee:				
1	57	60	99	94
2	77	84	93	93
3	81	89	93	92
4	123	144	91	86
Total [1]	79	85	94	93

COMBINED FALL CROPS OF 1935 AND 1936

Refugee 1000 to 1:				
1	21	20	91	90
2	79	93	95	84
Total [1]	50	74	93	89
Early Refugee:				
1	35	41	94	84
2	77	85	92	91
3	88	107	97	82
Total [1]	58	69	92	84

[1] Figures for total represent percentages based on totals of all harvests for a single crop, or weighted means.

TABLE 22.—*Analysis of variance of data entering into table 20*

Source of variation	Degrees of freedom	Mean squares for spring crops			
		Yield	Number of pods	Pod length	Weight per pod
Total	31	214.807	14.533	1.403	0.204
Diseased *v.* healthy	1	459.045	15.736	[1] 2.143	[2] 1.114
Between varieties	1	.005	1.901	[2] 23.516	.142
Between pickings	3	159.071	7.022	.327	.100
Between years	1	[1] 840.500	65.265	[1] 2.386	.096
Variety × disease	1	.935	.015	.008	.022
Variety × pickings	3	321.246	34.023	[1] 1.984	[2] 1.135
Variety × year	1	73.205	1.882	[1] 2.413	.029
Remainder (error)	20	192.220	18.130	.387	.049

Source of variation	Degrees of freedom	Mean squares for fall crops			
Total	23	99.235	6.141	11.322	2.130
Diseased *v.* healthy	1	[1] 1,355.740	[1] 14.978	[1] 1.409	[2] 1.397
Between varieties [3]	1	[1] 363.482	[1] 21.774	[2] 17.685	[2] 10.336
Between pickings [3]	2	[1] 257.632	[1] 15.470	[2] 69.847	[2] 10.298
Between years	1	8.882	.180	.532	[2] .781
Variety × disease [3]	1	18.726	.082	.006	.165
Variety × pickings [3]	2	161.632	12.297	[2] 48.033	[2] 7.310
Variety × year [3]	1	16.335	2.015	1.084	.002
Remainder (error)	14	48.693	3.333	.248	.077

[1] Significant with reference to error by odds of more than 19:1 but less than 99:1.
[2] Significant by odds of more than 99:1.
[3] Values involving variety or picking are exaggerated because Refugee 1000 to 1 gave a zero yield at the third picking in both years.

Despite the apparent general superiority in yield and number of pods of healthy over diseased plants in the spring crops, it should be noted that most of this occurs in the first two pickings. There are 3 out of 12 comparisons in yield in which infected plants outyielded the healthy ones, supposedly as a result of the healthy plants completing their commercially productive bearing somewhat earlier than the infected plants, which were retarded as well as reduced in ultimate development. As calculated from the behavior of single pickings, neither the variance for yield nor for pod number due to disease is significant with reference to error. Thus, although there is a tendency toward a reduction in total yield of these two spring crops by mosaic, the difference is not significant. The reductions in pod length and in individual pod weight, however, were significant, although less severe. Pod quality was definitely and consistently affected adversely in all pickings as well as in total yield.

The variances due to interaction between disease and year (not shown in table) and disease and variety (see table 22) for all factors measured were of extremely low values, closely approaching zero in some cases.

The differences between diseased and healthy plants of the fall crops were greater and more consistent than for the spring crops. Part of this may have been due to the early termination of all bearing after two or three pickings, thus preventing the diseased plants from surpassing healthy ones in those instances where the disease effect involved chiefly a retarding of bearing. On the other hand, table 20 suggests that fall damage from mosaic is so much more severe than spring damage that the infected plants would never yield significantly more at any one picking. In the fall crops variances due to disease were significant for yield, pod number, and length and weight of pod.

If yields are considered for total crop alone, without reference to what occurs within a season or at individual pickings, it is found that highly significant differences (odds greater than 99:1) exist between mosaic-affected and healthy plants (table 23). Differences for numbers of pods are moderately significant.

TABLE 23.—*Analysis of variance of yields and number of pods per plant for crop totals shown in table 20*

Source of variation	Analysis of spring crops alone			Analysis of all crops		
	Degrees of freedom	Mean squares for—		Degrees of freedom	Mean squares for—	
		Yield	Pod number		Yield	Pod number
Total	7	791.60	48.73	15	1,728.23	101.22
Diseased *v.* healthy	1	[1] 1,836.18	[1] 63.89	1	[1] 2,851.56	[2] 102.01
Between years	1	[1] 3,362.00	[1] 261.06	1	[2] 1,998.09	[2] 113.42
Between varieties	1	.02	7.41	1	538.24	62.41
Between seasons				1	[1] 18,090.25	[1] 1,059.50
Remainder (error)	4	85.75	2.19	11	222.31	16.45

[1] Significant with reference to error by odds of more than 99:1.
[2] Significant with reference to error by odds of more than 19:1 but less than 99:1.

CONCLUSIONS

Bean plants infected with mosaic early in the season yield appreciably less than healthy plants for the first two harvest periods. Differences based on total yield of fall crops alone are highly significant.

Pod lengths for mosaic-infected plants are slightly but significantly less than for healthy plants.

Individual pod weights for mosaic-infected plants are slightly but significantly less than for healthy plants.

The principal factor involved in reduction of yield by bean mosaic is reduction in number of marketable pods per plant.

SUMMARY

Certain cultural practices as compared with others may result in appreciable differences in the percentage of dry root rot infection on snap beans in the South. Root rot was more prevalent on beans planted 2 inches deep than on those planted 1 or 1½ inches deep. Planting early when the soil and weather were cool and wet was conducive to more dry root rot infection than later planting, although certain benefits of early planting generally tended to offset this disadvantage. No consistent relationship was noted between dry root rot infection and the kind and amount of fertilizer used, within the range of reasonable commercial practice. Application of fertilizer in a band 6 inches to one side of the row or as a top dressing resulted in markedly less dry root rot infection than application in the row.

Although none of the above-mentioned differences in percentage of dry root rot infection were accompanied by significant differences in yield, it is assumed that practices which tend to lessen root rot infection will, in years conducive to damage, result in less crop loss than practices favorable to heavy infection. In these studies there were greater differences in yields between crops and between years than between treatments.

Among 26 varieties of snap beans tested, significant differences were found in susceptibility to mosaic and to dry root rot infection, and also in yield. But neither mosaic nor root rot infection appeared to be responsible for the yield differences among the varieties in these studies. Differences in yielding capacity were apparently due to regional adaptations and varietal characteristics other than degrees of resistance to these two diseases.

Of a large number of seed treatments tested, none had a significant beneficial effect on yield, although the use of ethyl mercury tartrate resulted in slightly and significantly improved stands. The beneficial treatments appeared to be more effective with seeds sown under cool, wet conditions than those sown under more favorable conditions when they are less liable to disease infection.

The differences in yields and pod characters of mosaic-infected versus mosaic-free bean plants were quite striking in many instances. In general, plants infected early in their development yield appreciably less than healthy plants for the first two harvest periods, although they sometimes equal or even surpass disease-free plants for the late harvests. The economic loss resulting from delayed development of diseased plants may be much greater than that suggested by the total yield figures. Losses from mosaic were especially severe in fall crops of beans.

Mosaic-infected plants produced marketable pods that were slightly but significantly shorter and of less weight than those from healthy plants. The principal factor responsible for low yield of infected plants is reduction in number of marketable pods per plant.

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